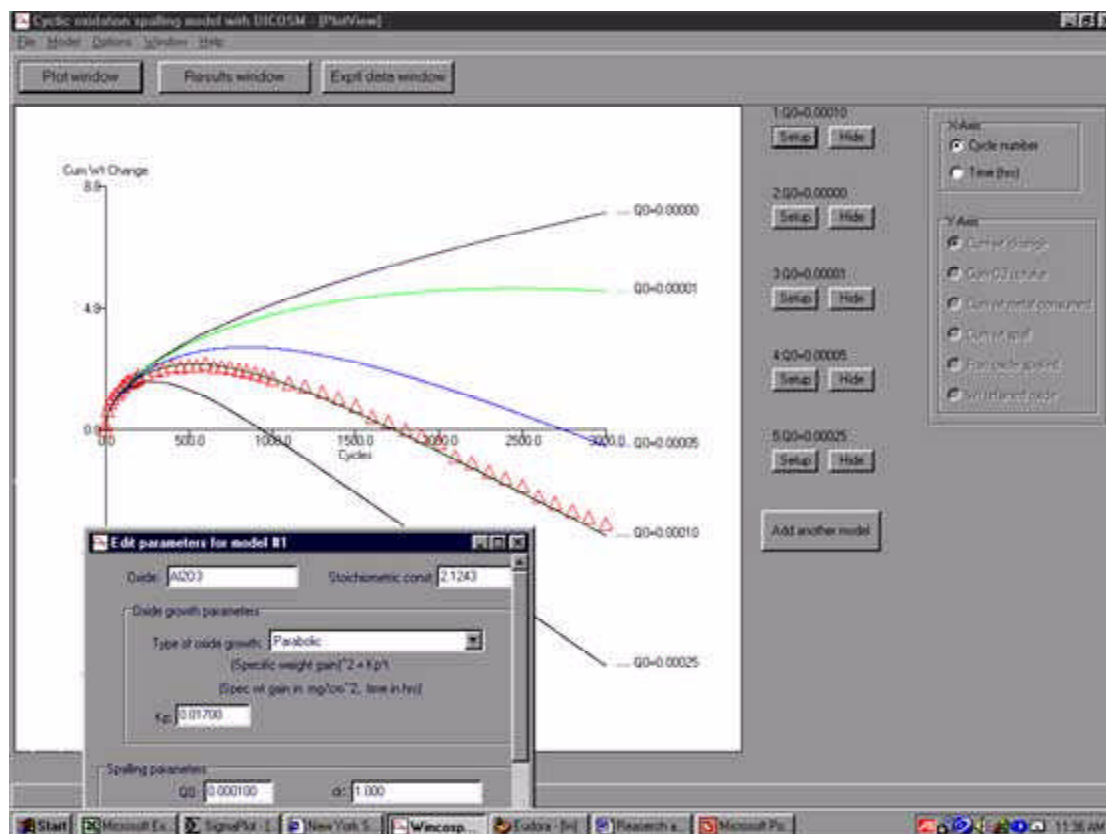# Cyclic Oxidation Modeling Program Rewritten for MS Windows

Turbine superalloy components are subject to high-temperature oxidation during operation. Protection is often conferred by coatings designed to form slow-growing, adherent oxide scales. Degradation by oxidation is exacerbated by the thermal cycling encountered during normal aircraft operations. Cooling has been identified as the major contributor to stresses in the oxidation scales, and it may often cause some oxide scale spallation with a proportional loss of protective behavior. Overall oxidation resistance is, thus, studied by the weight change behavior of alloy coupons during high-temperature cyclic oxidation in furnace or burner rig tests. The various characteristics of this behavior are crucial in understanding the performance of alloys at high temperatures. This new modeling effort helps in the understanding of the major factors involved in the cyclic oxidation process.

Weight change behavior in cyclic oxidation is typified by an initial parabolic weight gain response curve that eventually exhibits a maximum, then transitions into a linear rate of weight loss due to spalling. The overall shape and magnitude of the curve are determined by the parabolic growth rate, $k_p$, the cycle duration, the type of oxide scale, and the regular, repetitive spalling process. This entire process was modeled by a computer program called the Cyclic Oxidation Spalling Program (COSP) previously developed at the NASA Glenn Research Center (refs. 1 and 2). Thus, by supplying appropriate oxidation input parameters, one can determine the best fit to the actual data. These parameters describe real behavior and can be used to compare alloys and project cyclic oxidation behavior for longer times or under different cycle frequencies.

*Sample screen from the COSP for Windows cyclic oxidation modeling program showing the initial setup menu and plot window. Multiple plots for various spall constants and actual data points for NiAl(Zr) oxidized at 1200 °C show good agreement for the parabolic rate constant $k_p = 0.017$ mg$^2$/cm$^4$h and the spall constant $Q_o = 0.0001$.*
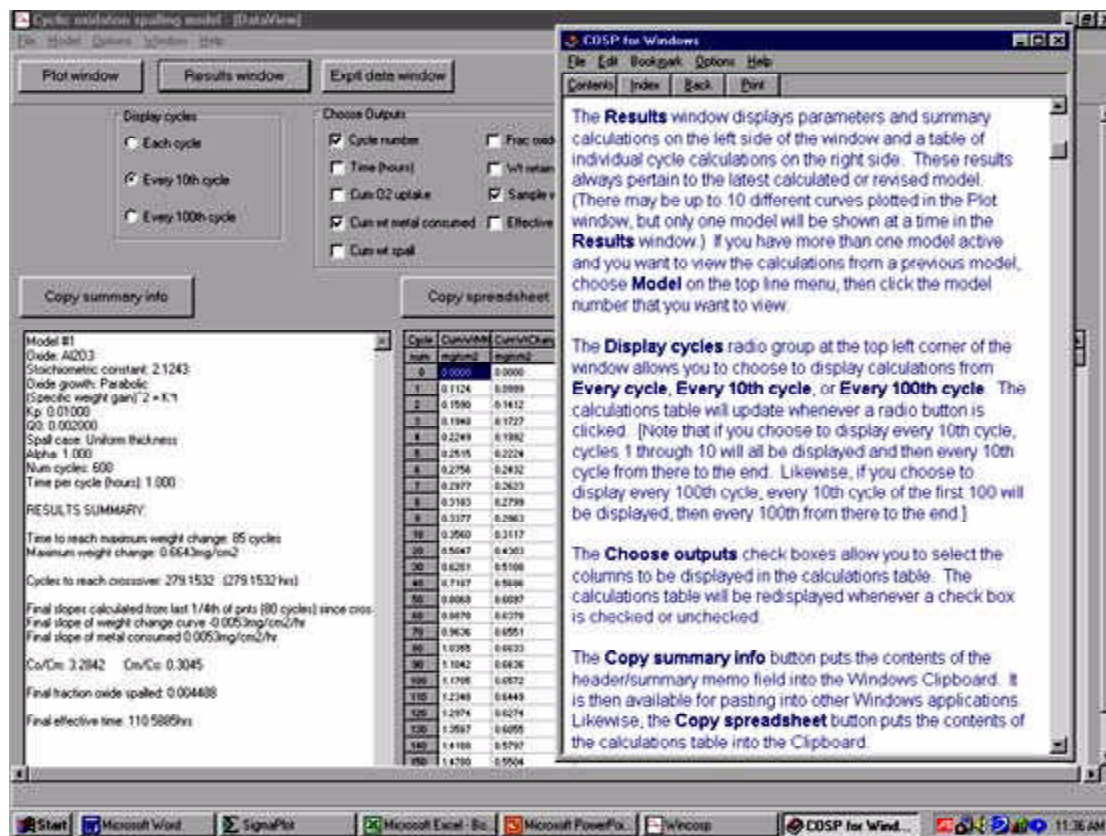Long description

Sample screen from the program in which all the parameters required to run the case model are input. The graphical output shows a typical weight-change curve. The data points are from an oxidation-resistant NiAl alloy tested at 1100 and 1200 °C. The alloy is nicely described by the model curves with two sets of growth and spalling constants.

This year, the program was rewritten to run under the MS Windows (Microsoft, Redmond, WA) operating system (ref. 3). This allows the major benefits of navigating between various control screens and interfacing with other applications. Point-and-click operating features include multiple drop-down menus for setting model input parameters, for importing experimental data for analysis, and for viewing quick, on-screen plots that show any of the six output parameters for up to 10 models. Families of model curves on the instant plot screen readily show the sensitivity to various input parameters and allow rapid and precise fitting to experimental curves. An example of the initial setup menu and plot window is shown in the preceding figure for the weight change behavior of an aluminum oxide scale. Five model curves are presented with various spalling parameters. One curve represents the best fit to the experimental data obtained for the 1200 °C cyclic

oxidation of NiAl.

The program can be operated conveniently while other MS Windows applications remain open for importing experimental weight change data, storing model output data, or plotting model curves in a graphics package. The program includes save and print options as well as a help file.

Along with the sample weight change, other salient terms are calculated--the existing scale weight and the cumulative amounts of oxygen consumed, metal consumed, and spall weight. These are all listed in a table accessed by the results window button. Key descriptive parameters (such as the number of cycles to reach the maximum weight gain and to reach zero weight change, the final weight loss slope, and the plateau in oxygen gain) are all highlighted as part of a summary text output. An example of the results table and the summary information are presented in the following figure, along with the pertinent help topic text. The COSP for Windows program is publicly available upon request.



*Sample screen for the results window and appropriate help text. Summary information and output data tables are presented for the selected model case.*
Long description

Numerical values produced by the models in table form. Columns are present for up to eight output categories. A text summary highlights some of the descriptive factors of the model (e.g., maximum weight change, time to reach maximum, and final weight loss rate).

# References

1. Lowell, C.E., et al.: COSP: A Computer Model of Cyclic Oxidation. Oxid. Met., vol. 36, nos. 1/2, 1991, pp. 81112.

2. Smialek, J.L., et al.: Cyclic Oxidation Testing and Modelling: a NASA Lewis Perspective. NASA/TM--2000-209769, 1999.

3. Smialek, J.L. and Auping, J.V.: COSP for WindowsStrategies for Rapid Analyses of Cyclic Oxidation Behavior. To be published, Oxid. Met., 2002. (Also NASA/TP--2002-211108, 2002.)

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